HWY-05-M-H035
Wilmer, Texas

ATTACHMENT #2

Forensic Tire Report - Bridgestone/Firestone

(29 pages)

BRIDGESTONE AMERICAS HOLDING, INC.

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March 17, 2006

VEHICLE FACTORS: TIRES AND TIRE MARKS

NTSB ACCIDENT INVESTIGATION

Description:	**Motorcoach Fire**
Location:	**I-45 Near Wilmer, Dallas Co., Texas**
Date:	**September 23, 2005**
NTSB Case No.:	**HWY-05-MH-035**

The subject matter concerns a motor vehicle accident that occurred on September 23, 2005, at about 6:07am. The vehicle is a 1998 MCI motorcoach, which was traveling northbound on Interstate 45 with a driver and 44 passengers who were evacuating from the Houston, Texas area as Hurricane Rita approached the coast. The motorcoach, which had pulled to the right side of the highway near Exit 269 in or near Wilmers, Texas (Dallas County), was engulfed in a fire that resulted in numerous fatalities and injuries.

At the request of the National Transportation Safety Board ("NTSB"), Bridgestone Americas Holding, Inc. ("BSA") and Bridgestone Firestone North American Tire, LLC ("BFNT") agreed to assist in the investigation of the subject accident. As part of the Vehicle Factors Group involved in the investigation, and on behalf of BFNT, I have been asked to examine and analyze the pertinent tires, wheels, and tire marks involved the subject accident. In addition, this report offers background information about the design, development, testing, manufacture, and performance of certain types of medium and heavy duty truck tires (see Appendix), including Firestone FS400 tires manufactured by BFNT or its predecessor Bridgestone/Firestone, Inc. (collectively, "Bridgestone/Firestone").

This report contains opinions and conclusions based on my education, experience, research, and investigation to date regarding the subject matter. Since the investigation is ongoing by the NTSB and others, and as additional information may become available, I reserve the opportunity to modify or amend this report.

Accident Summary

Investigators determined that the motorcoach experienced an earlier breakdown incident, approximately 28 miles prior to the scene of the fire. The following summarizes my understanding of the incidents leading up to the accident:

First Incident: Lock-Up Leading to Flat Tire

At approximately 3:30am on September 23, 2005, the motorcoach was traveling northbound on I-45 and experienced a lock-up of the tire/wheel assembly on the right side of the rearmost axle. This steerable, air-spring suspended axle, known as axle #3 and also as the "tag" axle, has disc brakes and utilizes a single tire per side. The motorcoach stopped in the right-most lane between milepost 241 and Exit 242 in a two-lane (northbound) construction zone. A tire skid mark leading to this location measured about 6,802 feet. The flat tire and wheel assembly was removed and exchanged with a spare tire/wheel assembly by a mobile service. The spare tire/wheel assembly was obtained from the coach's spare tire carrier; the flat tire/wheel assembly was then placed into the same carrier, which is horizontally-oriented at the front of the coach. Thereafter, the motorcoach resumed northbound travel on I-45.

For purposes of this report, the pertinent tire/wheel involved in this initial lock-up incident will be referred to as "Subject Tire #1," "Subject Wheel #1," and/or "Subject Tire/Wheel Assembly #1."

Second Incident: Lock-Up Leading to Fire

At approximately 6:07am on September 23, 2005, a passing motorist observed that the motorcoach appeared to have glowing/red heat coloration of the right side, rearmost wheel/hub. The motorist stopped his vehicle in front of the coach in the left-most lane of this three lane (northbound) section of I-45 just south of Exit 269, and attempted to advise the driver of his observations. Subsequently, the motorcoach resumed travel in the left-most lane and progressed several hundred feet before a second tire/wheel lock-up condition resulted. The coach ultimately crossed over the center and right lanes and came to stop on the right-most shoulder of the highway just past Exit 269. Approximately 1,520 feet of skid markings lead to this location, initiating from the left lane/center lane dividing line in an area where numerous tire, rubber, and other components were recovered. The driver, upon exiting the coach, observed flaming from the right rear wheel well; thereafter, the coach was engulfed by fire.

For purposes of this report, the pertinent tire/wheel involved in this second lock-up incident will be referred to as "Subject Tire #2," "Subject Wheel #2," and/or "Subject Tire/Wheel Assembly #2."

Examination and Material Review

On September 28-30, 2005, I conducted a field inspection of the subject motorcoach and tires/wheels, an exemplar motorcoach, and the incident scenes along I-45 near Dallas. On November 22-23, 2005, I conducted an examination of Subject Tire/Wheel Assembly #1, Subject Wheel #2, and remnants of Subject Tire #2 at our Product Analysis Laboratory in Akron, Ohio.

Additionally, among the materials I have reviewed are over 2,000 photographs and NTSB Group Chairperson On-Scene Investigation Narrative reports with attachments/appendices, including those of the Fire and Explosion, Human Performance, Highway, Evidence Documentation and Mapping, Survival Factors, Vehicle, and Motor Carrier Groups.

Conclusions

<u>First Incident: Lock-Up Leading to Flat Tire</u>

1. The first incident involving Subject Tire/Wheel Assembly #1 is the result of a lock-up condition of the tire/wheel assembly. The tire was abraded by the road completely through the tread, belts, and casing to the air cavity, resulting in a rapid loss of inflation pressure. A skid mark indicative of the lock-up condition extends a total of about 6,802 feet.
2. At the initiation of the lock-up, the skid mark exhibits a distinct appearance of the five tread ribs and is indicative of an inflated tire. The skid mark transitions to a solid appearance and ultimately to a wider appearance composed of numerous essentially parallel marks. The tire became flat an estimated 1,500 feet from the initiation of the lock-up.
3. The tire and wheel, though damaged by fire, exhibit abrasions consistent with the skid mark. The combination of the skid mark evidence and the tire/wheel itself indicate that the lock-up condition persisted, without substantial rotation, for the entire skid distance.

4. Subject Tire #1 does not exhibit a defective or unreasonably dangerous condition in design or manufacture and is fit for the purposes for which it was intended. I am not aware of any design or manufacturing condition of the subject tire that would preclude it from complying with the DOT Federal Motor Vehicle Safety Standards, including 49 CFR §571.119, applicable at the time of its manufacture.

Second Incident: Lock-Up Leading to Fire

5. Although Subject Tire #2, the spare tire applied to the right rear of the tag axle, was predominantly destroyed by fire, evidence indicates that prior to the fire the tire most likely failed under the stress and strain of cyclic deflection with increasing inflation pressure and excessive application of heat—with resulting damage—to the tire casing.
6. Numerous tire and rubber pieces recovered by investigators from the highway in an area prior to the initiation of the skid mark are consistent with components of steel-bodied, steel belted radial tires used in medium truck and bus applications. These particular pieces are from the bead area of such a tire and are composed of steel cord wrap-around bead reinforce/chafer, woven fabric toe reinforce/chafer, and woven fabric flipper components. Based on the characteristics and condition of these pieces and the location of their recovery, they are most likely remnants of Subject Tire #2.
7. At least 60 to 100 feet prior to the skid mark, Subject Tire #2 most likely failed in a manner whereby the radial body ply pulled out, or un-wrapped, from around the bead in a localized area and resulted in a rapid loss of inflation pressure. During the failure and/or with subsequent tire/wheel rotations, torn pieces of the tire, particularly from the bead area, were deposited on the highway.
8. Ultimately, the tire and wheel initiated a lock-up condition exhibited by the skid mark, which extends for about 1,520 feet. The final portion of the skid mark and numerous tire/rubber pieces recovered from the highway exhibit soft, pliable appearance/residue consistent with excessive heat damage.
9. Because the vast majority of Subject Tire #2 is unavailable and since the bead area pieces recovered at the scene are not consistent with design/component materials utilized by Bridgestone/Firestone-related entities, I cannot definitively identify the manufacturer, model, size, or date of production of the subject tire. Nor can most aspects of the tire's pre-accident condition be determined; for instance, it is not known whether the tire exhibited characteristics of proper care/maintenance, whether it was previously damaged, or whether there was adequate tread depth. However, none of the recovered tire pieces, albeit limited in quantity and scope, appear to exhibit any defective or unreasonably dangerous characteristics in design or manufacture.

Front Axle Tire Load Capacity

10. The tires applied to the subject motorcoach's front steer axle (axle #1), size 11R22.5 Load Range G, are improper in size and load capacity according to MCI's specifications. With a front GAWR of 7,258 kg (16,000 lbs), the motorcoach could overload the 11R22.5-G tires by about 30%.

Background

First Incident: Lock-Up Leading to Flat Tire

Reports indicate that at approximately 3:30am on September 23, 2005, the motorcoach was traveling northbound on I-45 and experienced a lock-up of the tire/wheel assembly (Subject Tire/Wheel Assembly #1) on the right side of the rearmost axle (axle #3, or "tag" axle).

Figure 1, a southbound view from the FM 1126 overpass, shows approximately the first 200 feet of the skid mark in the right-most lane of northbound I-45 with the initiation point just north of the exit ramp for Exit 239. In Figures 2 and 3, the five ribs of the tread can be observed in the skid mark.

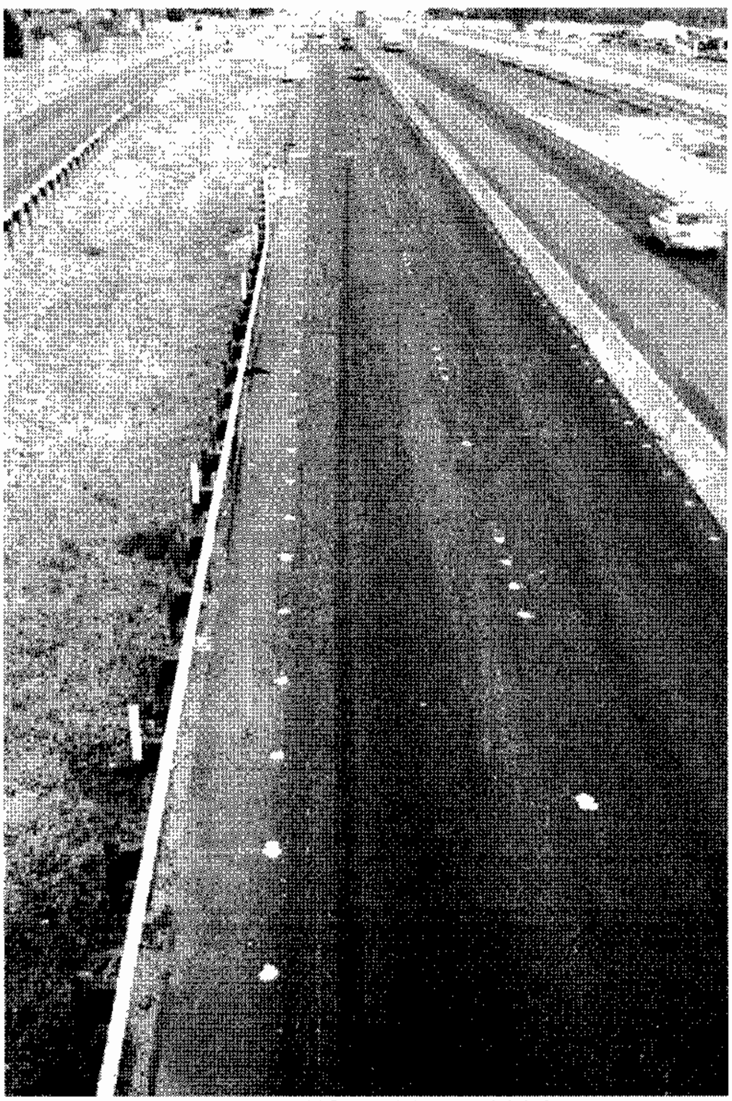


Figure 1: NTSB-092805-008.jpg

(6)

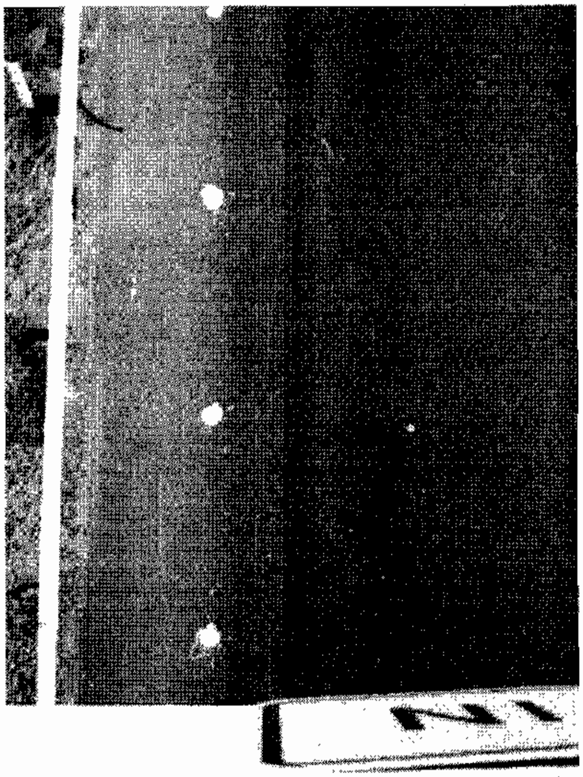


Figure 2: NTSB-092805-009.jpg

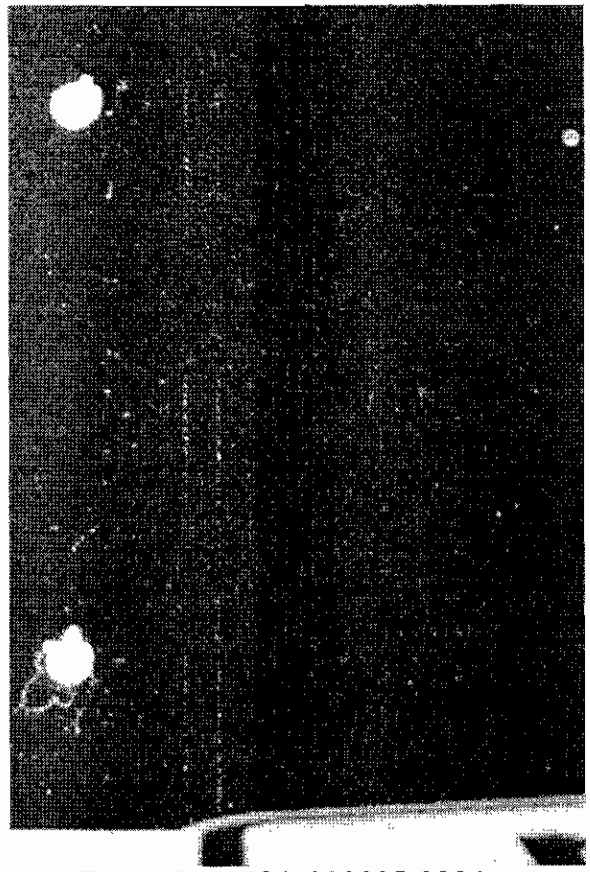


Figure 3: NTSB-092805-009.jpg
(enlarged/cropped)

7

Figure 4 shows the skid mark at approximately 1150 feet as essentially a solid mark, absent a distinct tread rib appearance.

Air loss is estimated to have occurred approximately 1500 feet from the initiation of the skid in an area where the solid skid mark transitions to a flat tire appearance between the merging traffic sign and the entrance ramp from the frontage road, as shown in Figures 5 and 6 (a northbound view from the FM 1126 overpass).

A view of the flat tire skid mark at about 1750 feet is shown in Figure 7.

Figures 8 and 9 show the termination point of the skid mark between milepost 241 and Exit 242, approximately 6802 feet from initiation. In Figure 8, abrasion of the asphalt by the alloy wheel can be more readily observed along the right edge of the skid.

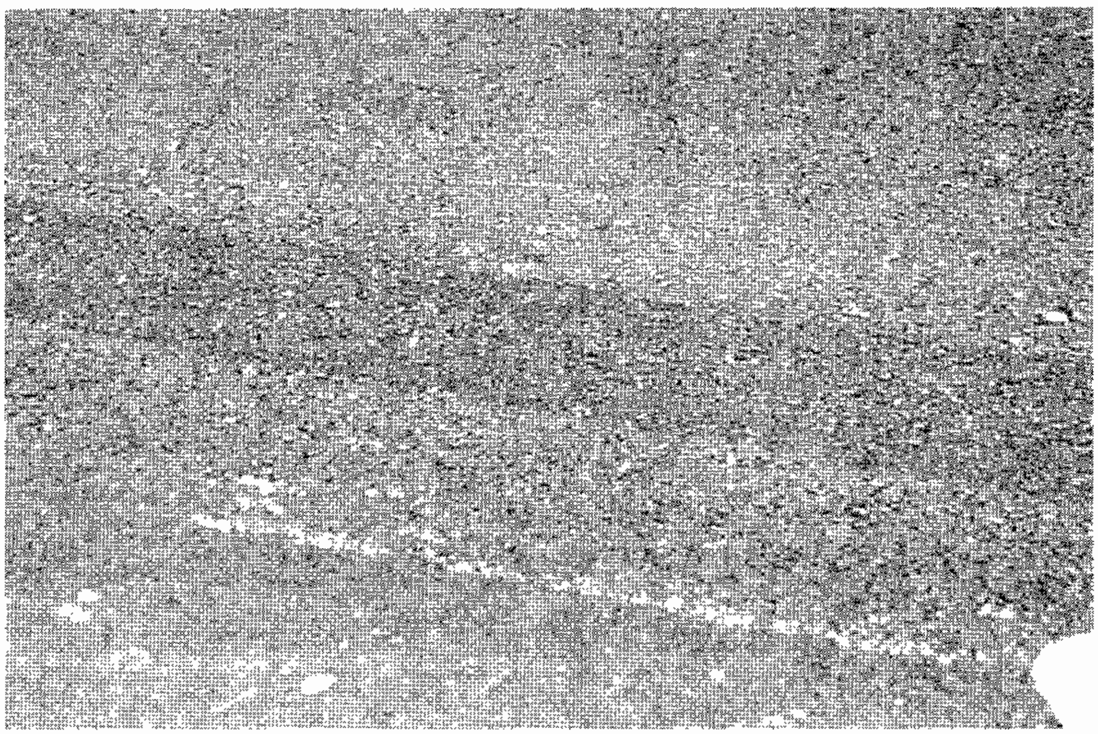


Figure 4: NTSB-092805-018.jpg

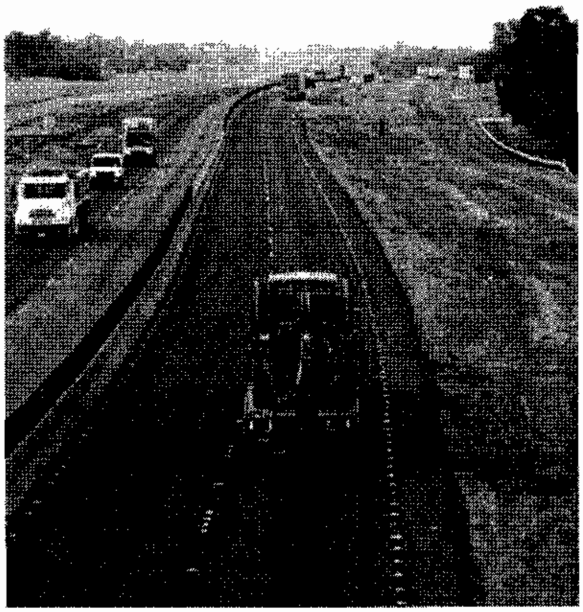


Figure 5: NTSB-092805-014.jpg

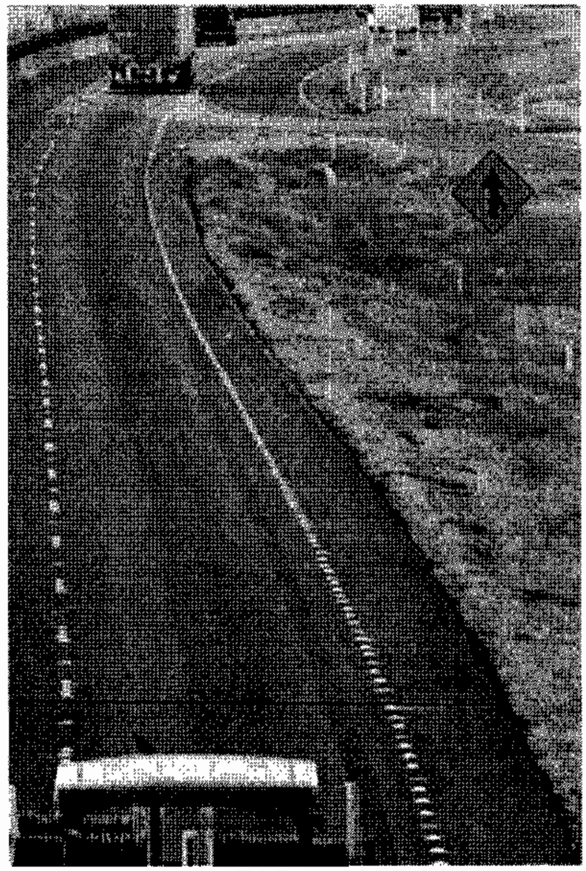


Figure 6: NTSB-092805-014.jpg
(enlarged/cropped)

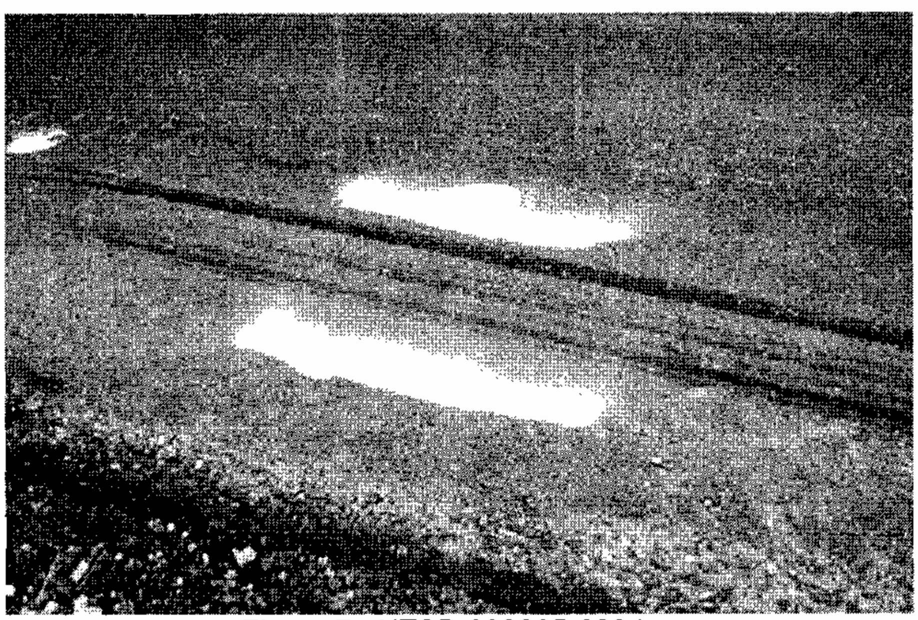


Figure 7: NTSB-092805-023.jpg

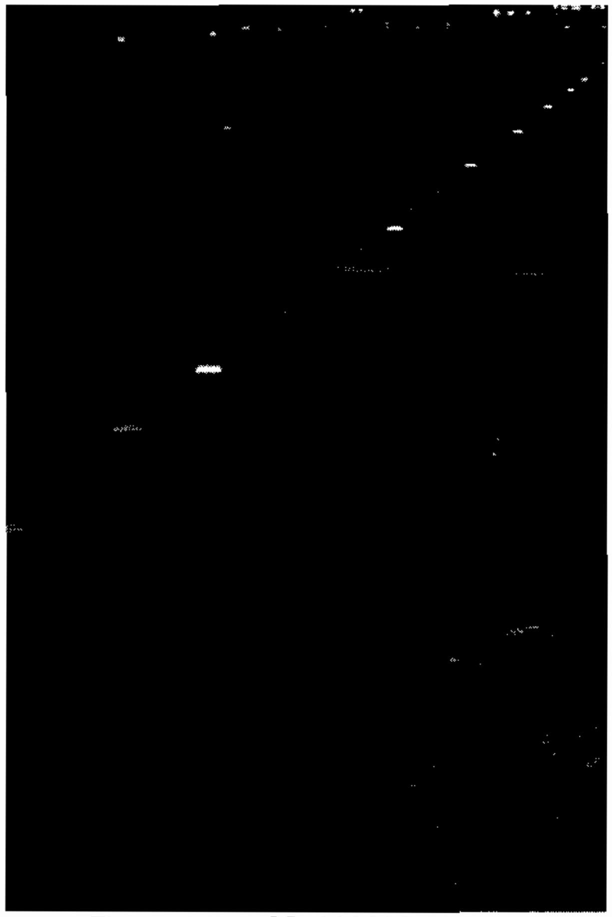


Figure 8: NTSB-092805-055.jpg

Figure 9: NTSB-092805-053.jpg

My understanding is that the flat tire and wheel assembly (Subject Tire/Wheel Assembly #1) was removed and exchanged with a spare tire/wheel assembly (Subject Tire/Wheel Assembly #2) by a mobile service. The spare was obtained from the coach's spare tire carrier and the flat tire/wheel assembly was placed into the same carrier, which is horizontally-oriented at the front of the coach. Figure 10 shows Subject Tire/Wheel Assembly #1 prior to removal from the spare tire carrier by investigators. Figure 11 is a photo of the assembly subsequent to removal from the carrier, with a particular view of the tread and outboard sidewall showing the predominant abrasion damage that resulted in air loss.

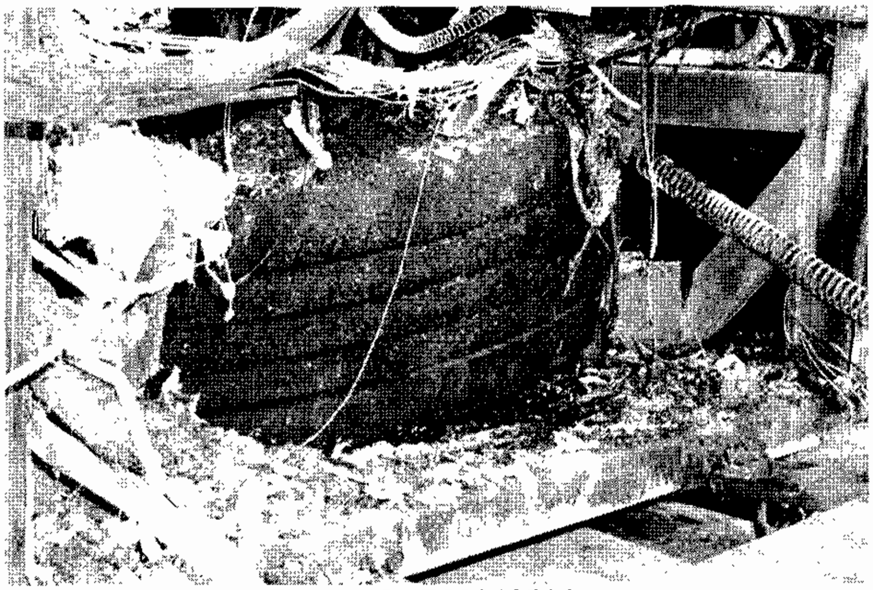


Figure 10: P0001651.jpg

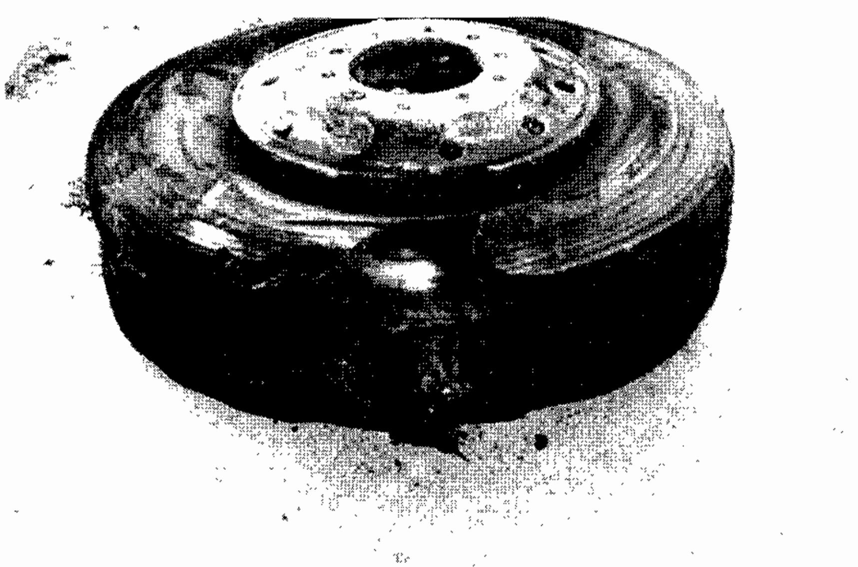


Figure 11: P0001668.jpg

Figure 12 shows the predominant abrasion damage to Subject Tire/Wheel Assembly #1 from a view of the tread and inboard sidewall. Figure 13 shows the abrasion damage to the outboard flange of the wheel.

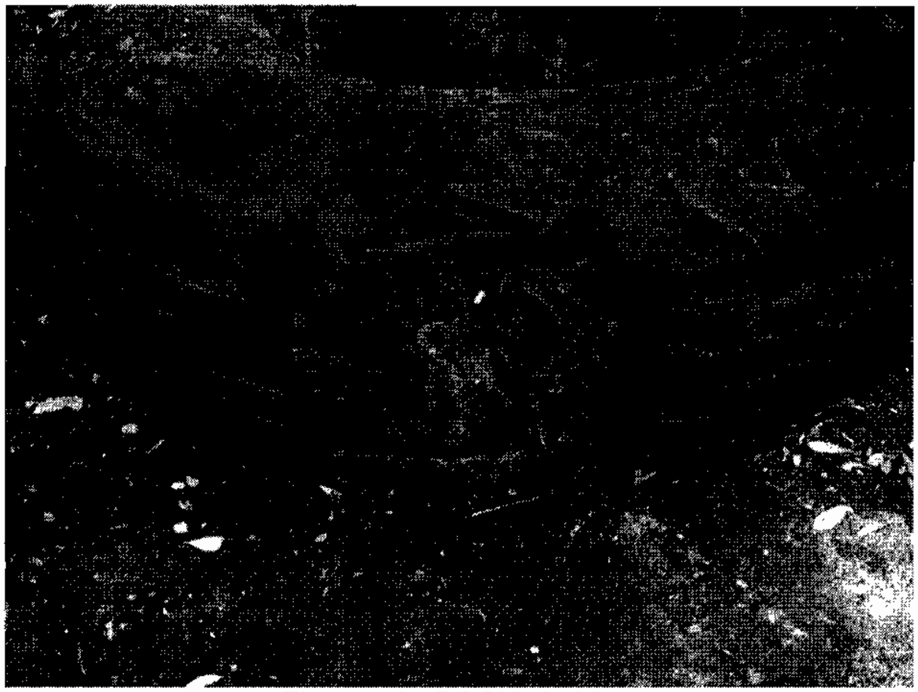


Figure 12: DSCN1919.jpg

Figure 13: 051326-B108.jpg

Second Incident: Lock-Up Leading to Fire

Reports indicate that at approximately 6:07am on September 23, 2005, a passing motorist observed that the motorcoach appeared to have glowing/red heat coloration of the right side, rearmost wheel/hub. The motorist stopped his vehicle in front of the coach in the left-most lane of this three lane (northbound) section of I-45 just south of Exit 269, and attempted to advise the driver of his observations. Subsequently, the motorcoach resumed travel in the left-most lane and progressed several hundred feet before a second tire/wheel lock-up condition resulted.

The highway leading to the skid mark is shown in the photo in Figure 14, taken from a vantage point approximately 120 feet prior to the skid mark. Between the first two cones in the photo, orange marking paint on the highway identifies "TIRE" in three locations in the center lane, representing where certain tire/rubber pieces were recovered by investigators. Figures 15 and 16 are closer views of the initiation of the skid mark.

The coach ultimately crossed over the center and right lanes and came to stop on the right-most shoulder of the highway just past Exit 269. Approximately 1,520 feet of skid markings lead to this location, shown in Figure 17. A close view of the tire mark at this end, shown in Figure 18, reveals a softened, gum-like appearance.

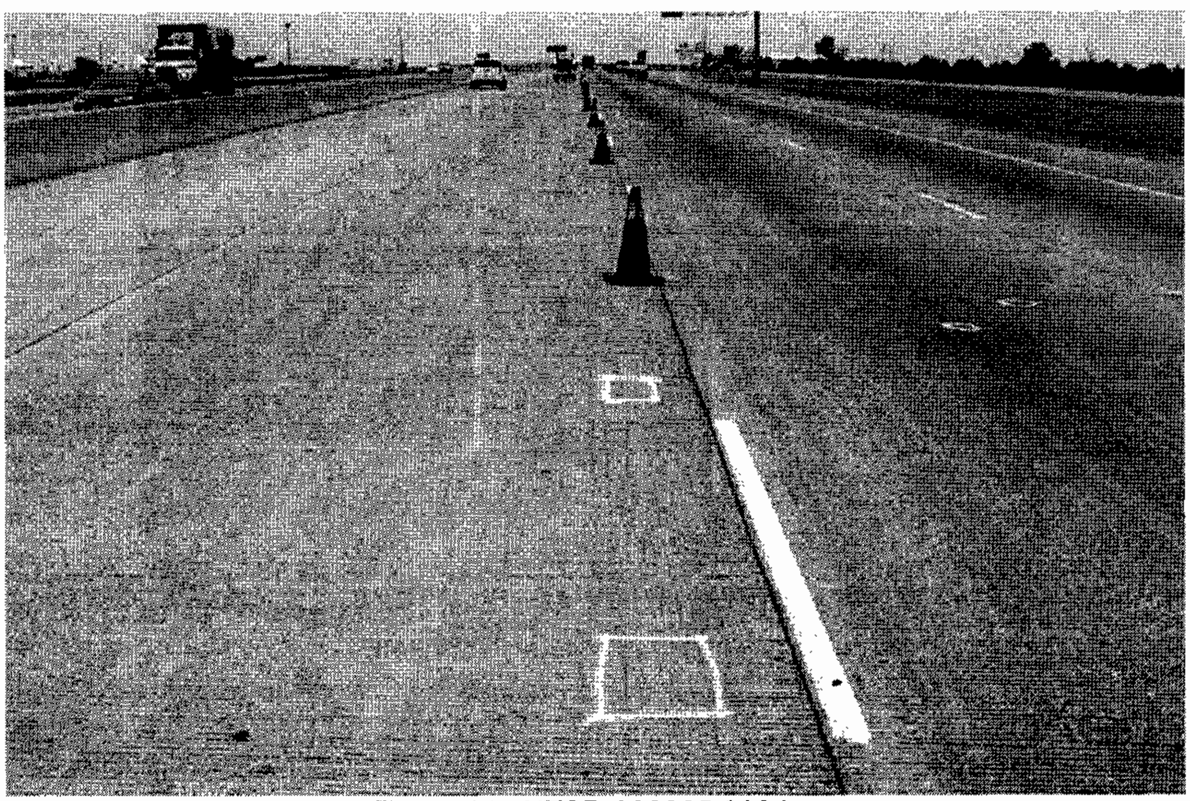


Figure 14: NTSB-093005.082.jpg

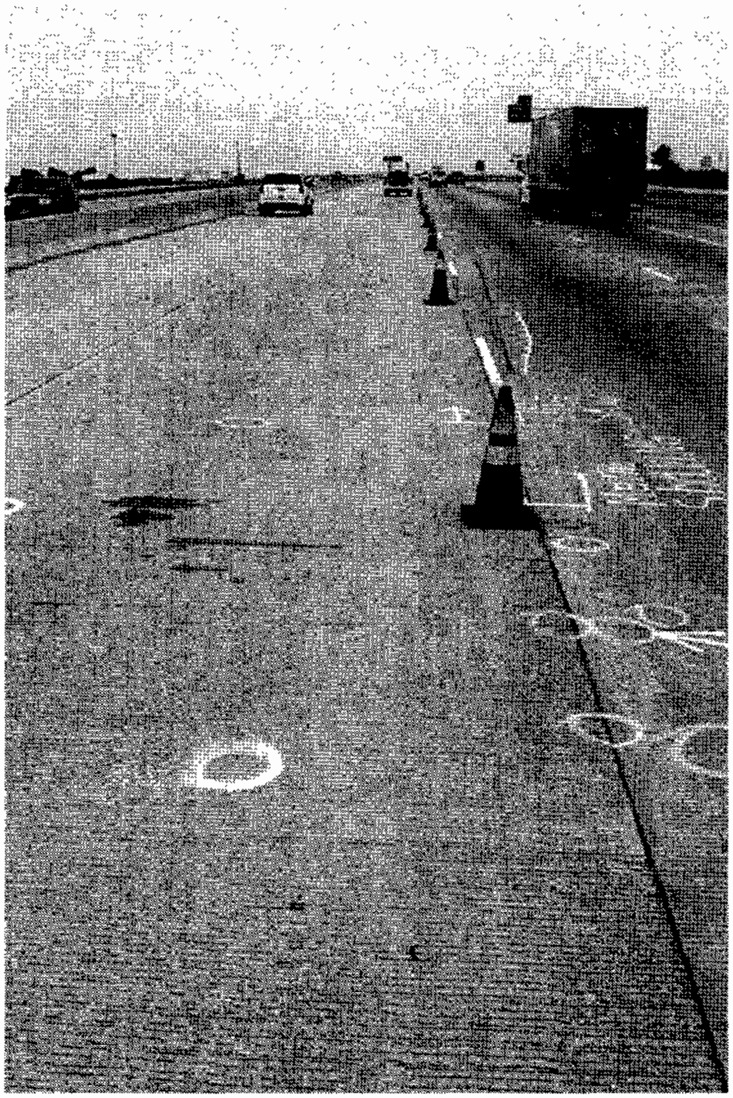


Figure 15: NTSB-093005.092.jpg

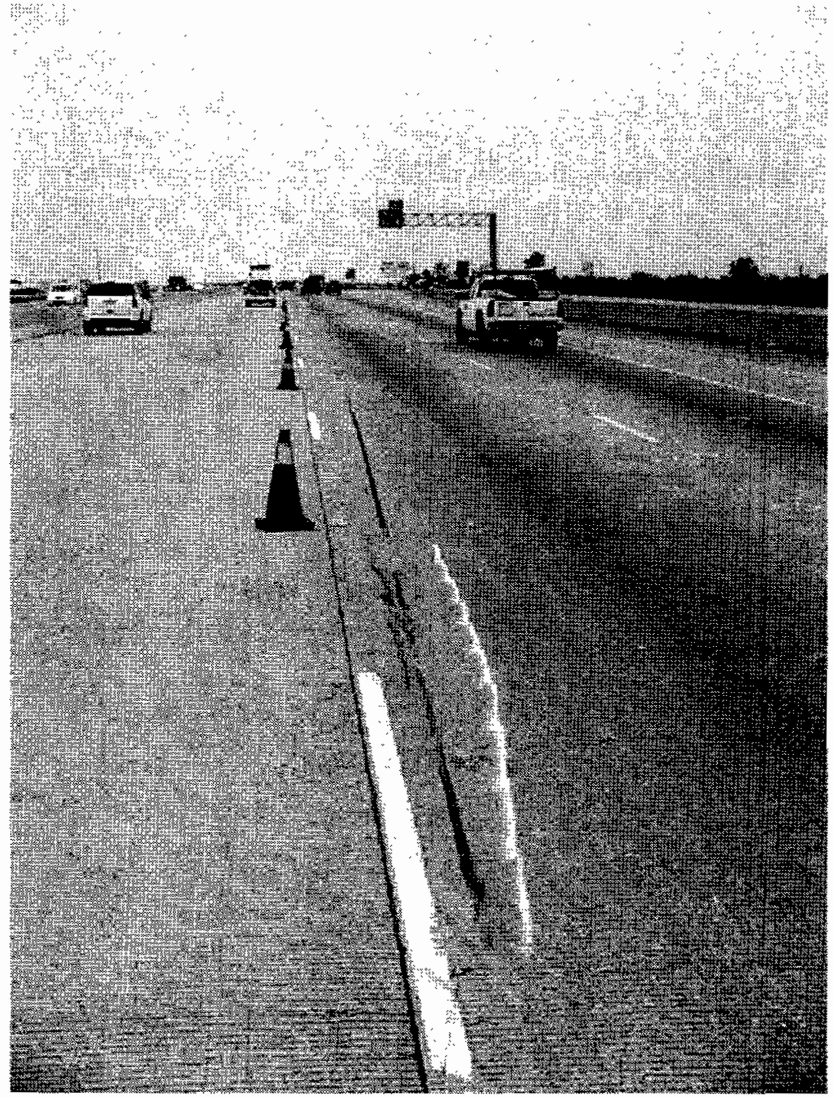


Figure 16: IMG_0509.jpg

(14)

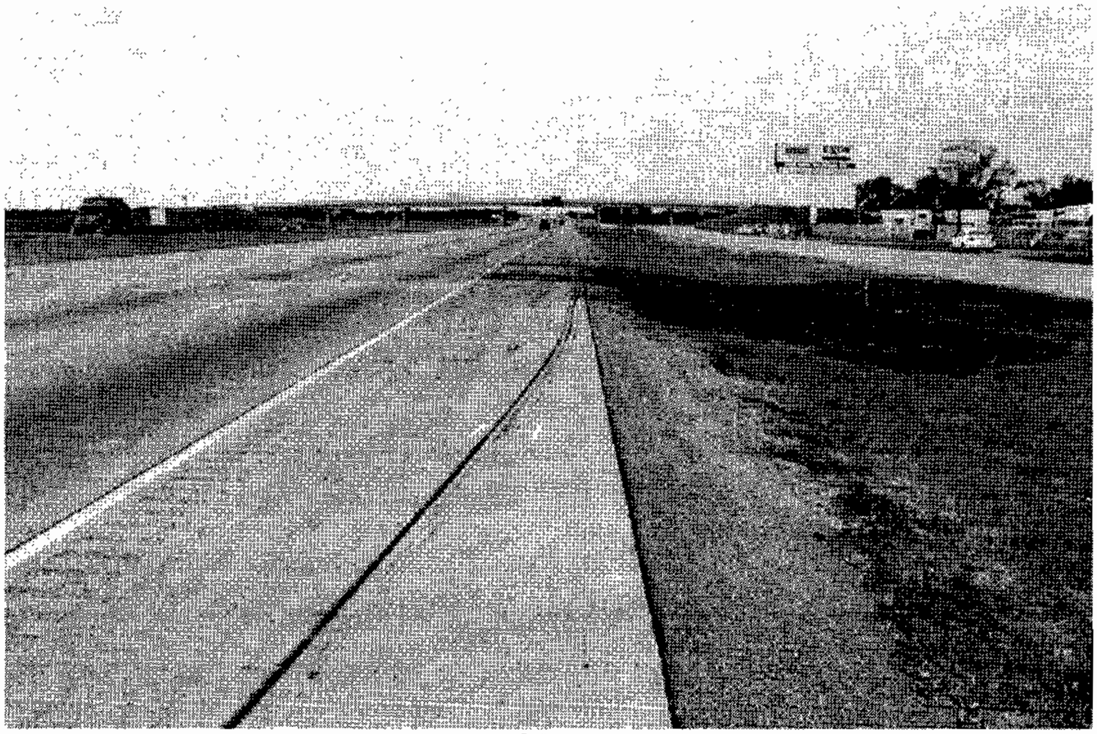


Figure 17: NTSB-092905-061.jpg

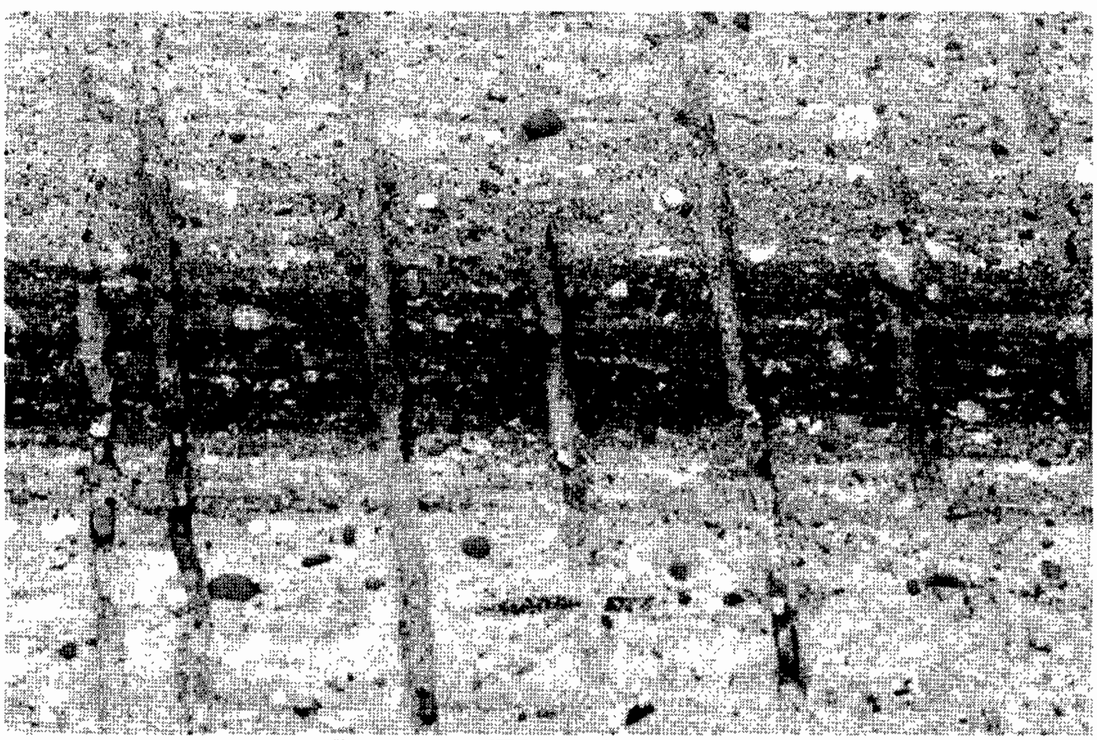


Figure 18: NTSB-092905-064.jpg

Of the tire/rubber pieces recovered from the highway by investigators, Figure 19 shows the larger bead area pieces of Subject Tire #2 which have steel cord wrap-around bead reinforce/chafer and woven fabric bead toe reinforce/chafer. In Figure 20, numerous additional bead area pieces are shown, including pieces of a woven fabric bead flipper component.

After the fire was extinguished, the tire/wheel on the right side of axle #3 (Subject Tire/Wheel Assembly #2) had an appearance as shown in Figure 21. A closer view of the wheel contact with the road surface as it appeared after debris was removed by investigators is shown in Figure 22.

Once Subject Tire #2 was deflated and entered the lock-up condition, more of the tire became in direct contact with, or more proximate to, the central portion of the wheel/hub assembly. Contact with, or close proximity to, a heat source could cause the tire to ignite, given sufficient time and temperature among other factors.

Specific self-ignition temperature data for one type of rubber is not necessarily the same as that for another type of rubber, nor of the tire taken as a whole. For instance, truck/bus steel radial tires, like other tires, can be composed of more than ten different rubber compounds. Considering that the bead area pieces recovered at the scene are not consistent with design/component materials utilized by Bridgestone/Firestone or other Bridgestone- or Firestone-related entities, the rubber compounds used in Subject Tire #2 are unknown to me. However, given typical compounding of tire rubber utilizing basic ingredients such as oil, carbon black, and polymer/natural rubber, it is reasonable to conclude that typical tire rubber compounds would have self-ignition temperatures that are not far ranging from the realm of 430°C (800°F) at atmospheric pressure.

Prior to self-ignition, excessive heat generation by a tire, and/or application of excessive heat from an external source, can cause a loss of desired rubber compound material properties and significant structural damage. For instance, heat-accelerated reversion of rubber is a process that is generally occurring by 205°C (400°F). Additional fatigue-related damage is inflicted from the stress/strain of inflation pressure and cyclic deflection during operation. In other words, a tire experiencing increasing, excessive heat build-up during operation is accelerating towards failure. The failure, and any ignition, of Subject Tire #2 is consistent with the tire having been exposed to excessive, externally-generated heat, according to my understanding of the accident investigation to date.

Figure 19: 051326-C002.jpg

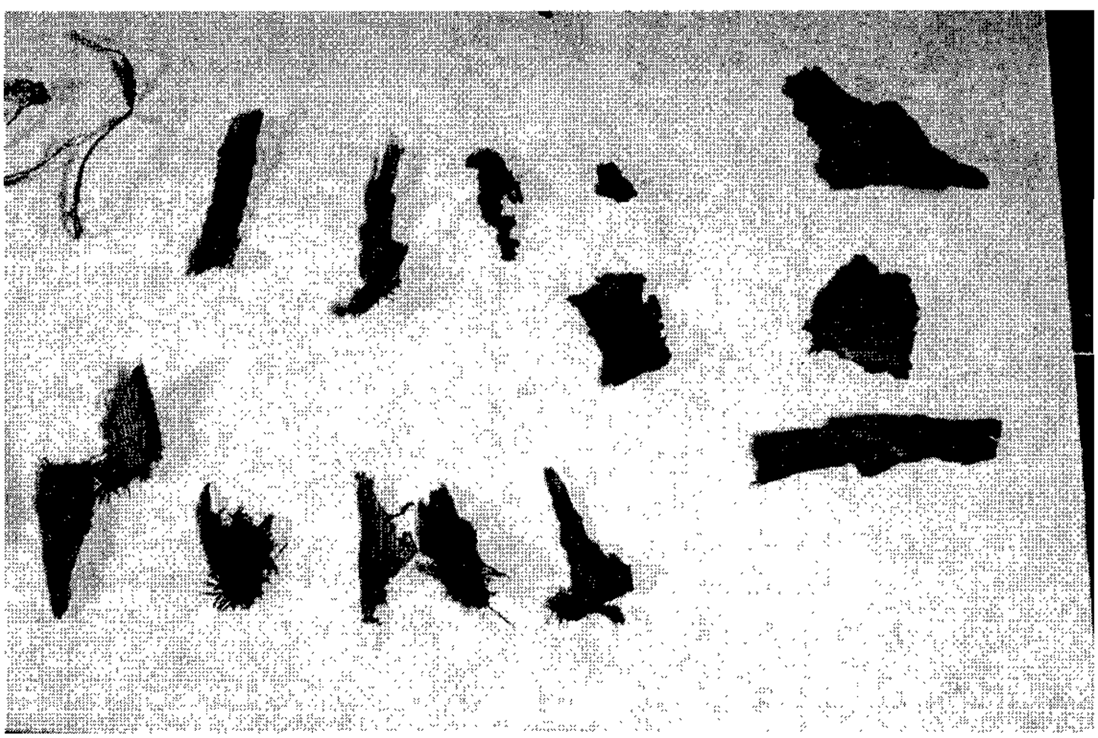


Figure 20: 051326-C003.jpg

Figure 21: P0000891.jpg

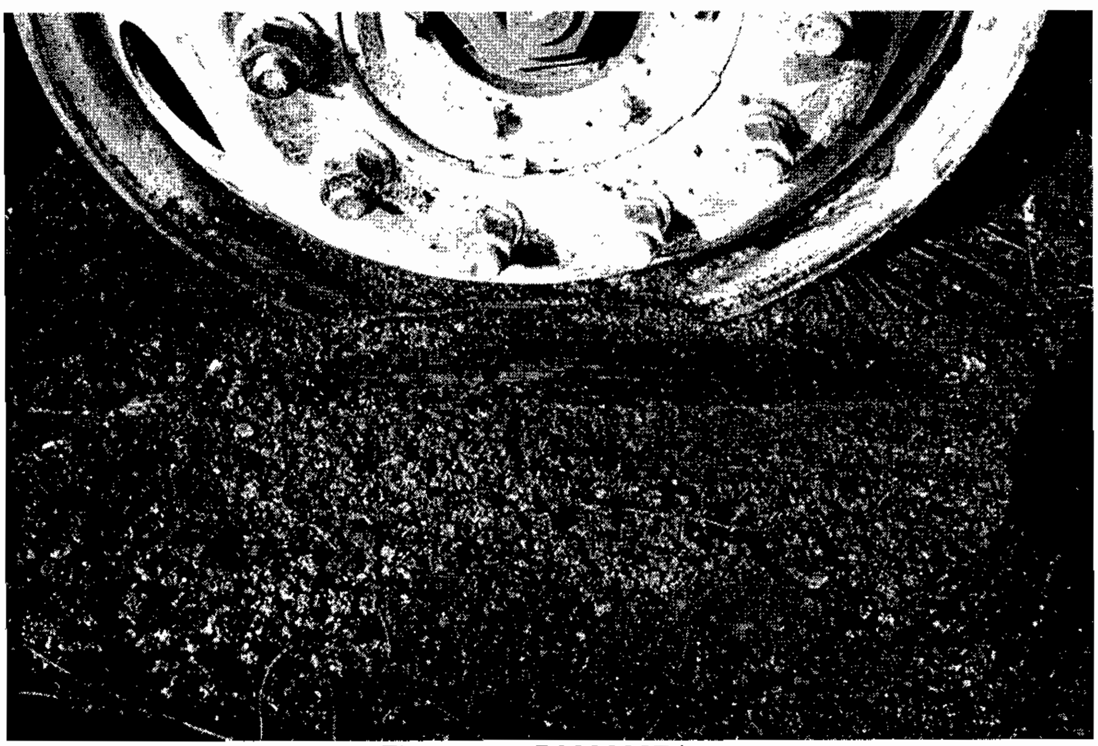


Figure 22: P0000907.jpg

Tire Identification

Subject Tire #2, from right side of the tag axle (#3), was essentially consumed by the fire, with only remnants of the bead area recovered from the highway. All of the remaining tires on the motorcoach were significantly damaged by heat/fire; most tire markings were obliterated and none had visible Department of Transportation (DOT) serial codes. Aside from the predominantly destroyed Subject Tire #2, remnants of tread and other visible markings assisted in identifying the tire or determining consistency with certain tire sizes and models. Using the graphic in Figure 23, refer to Tables 1 and 2 for the characteristics of the tires identified on the subject motorcoach.

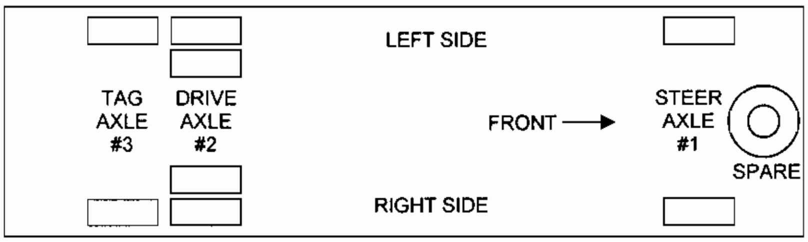


Figure 23: Motorcoach Tire Positions

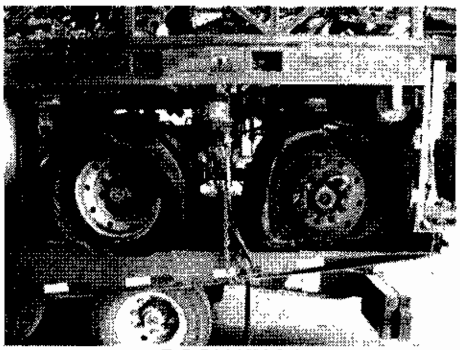
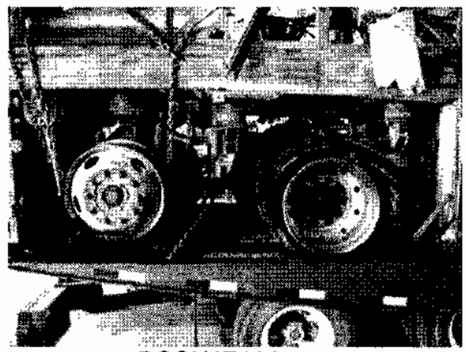
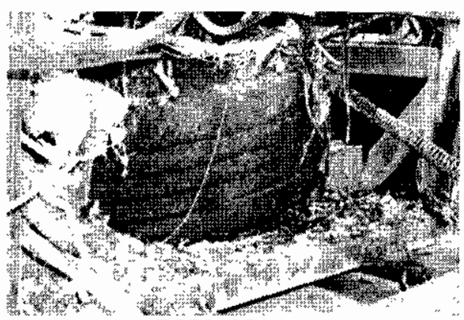
Axle*	Left Side	Right Side
1	Consistent with Dayton Rib Radial.All Position 11R22.5 Load Range G	Dayton Rib Radial All Position 11R22.5 Load Range G
2	Both tires consistent with Firestone FS400 315/80R22.5	Both tires consistent with Firestone FS400 315/80R22.5
3	Consistent with Firestone FS400 315/80R22.5	(not present) *See* Note 1
Spare	Firestone FS400 315/80R22.5 Load Range J *See* Note 2	

*Refer to Figure 23

Table 1: Motorcoach Tire Identification

Notes:

1. Subject Tire#2: Components/materials that comprise certain bead area pieces recovered from the highway at the scene leading to the fire (i.e. Figures 19 and 20) are not consistent with those utilized by Bridgestone/Firestone or other Bridgestone- or Firestone-related entities.
2. Subject Tire #1: The tire/wheel assembly recovered from the spare tire carrier after the fire was the flat tire/wheel assembly from the right side of tag axle #3 (Figures 10-13) involved in the first incident (lock-up leading to the flat tire).

Axle*	Left Side	Right Side
1	 ← Front DSCN1737.jpg	 DSCN1744.jpg Front →
2 and 3	 ← Front DSCN1738.jpg	 DSCN1741.jpg Front →
Spare	 P0001651.jpg	

*Refer to Figure 23

Table 2: View of Motorcoach Tires

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Tire Application and Load Capacity

According to MCI, the subject motorcoach had axle load ratings and tire application specifications as shown in Table 3.

Axle*	GAWR	Tire Size	Inflation	Wheel
1	16,000 lbs (7,258 kg)	315/80R22.5 Load Range J	120 psi	9.00x22.5
2	23,000 lbs (10,432 kg)	315/80R22.5 Load Range J	90 psi	9.00x22.5
3	16,000 lbs (7,758 kg)	315/80R22.5 Load Range J	120 psi	9.00x22.5

*Refer to Figure 23

Table 3: Motorcoach Axle Ratings and Tire Specifications

The tires applied to the subject motorcoach as noted in Table 1 have load/inflation capacities noted in Table 4.

Tire Size	Load Range	Single Usage		Dual Usage	
		Max Load	@ Inflation	Max Load	@ Inflation
11R22.5	G	6175 lbs (2800 kg)	105 psi	5840 lbs (2650 kg)	105 psi
315/80R22.5	J	6670 lbs (3030 kg)	90 psi	6070 lbs (2750 kg)	90 psi
		8270 lbs (3750 kg)	120 psi	7610 lbs (3450 kg)	120 psi

Table 4: Tire Load/Inflation Capacities

Therefore, from the above, note the following:

1. The MCI motorcoach specified suitable tire size and inflation pressures to carry the maximum rated axle loads of the vehicle.
2. The front tires actually applied to the subject motorcoach, size 11R22.5-G, were improperly sized/rated and did not have suitable load capacity to carry the front axle maximum rated load. Each tire was potentially overloaded by 1825 lbs, or approximately 30%.

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In closing, this report summarizes my examination and analysis to date and my understanding of events and evidence presented to me during the on-going investigation by the NTSB, Dallas Sheriff's Office, Texas Department of Public Safety, and Federal Motor Carrier Safety Administration, among others. If additional information becomes available regarding the subject accident, I reserve the opportunity to modify or amend opinions and conclusions contained in this report.

Photographs taken during the field inspections and laboratory examinations have been previously provided to the NTSB. We will continue to hold the tire/wheel evidence in our laboratory's secured storage facility until disposition direction is provided by the NTSB or authorized law enforcement agency.

Respectfully Submitted,

Brian J. Queiser

Brian J. Queiser

APPENDIX

The Essence of Steel Belted Radial Tires

A tire is a highly engineered, complex product, which is the result of a blend of chemistry and engineering. The chemistry pertains to the numerous rubber compounds used in the various components of the tire and the engineering involves the composite structure of the tire, which includes fabrics of steel, polyester, nylon, and/or other cords. From this standpoint, it is arguably the most technically advanced component of the entire vehicle.

Manufacturing a tire is also complex. A tire is a composite, laminate assembly of numerous individually prepared components—which are items of defined materials, configurations, and applications. At the assembly stage, the rubber compounds that make up the tire are soft, pliable, and tacky and the tire is commonly called "green" because it has not yet taken on its final shape and physical properties. The "green" tire is then physically shaped within a mold and chemically transformed, its components reacting and bonding, its rubber compounds becoming tough and resilient—all through a curing process (called vulcanization) involving heat, pressure, and time. Ultimately, the tires are individually inspected and evaluated for uniformity.

Each individually prepared component in a tire has a particular role to contribute to the tire's performance. The components work in conjunction with one another to form an integrated tire product. Many components are comprised of one or more rubber compounds, while others are composites of rubber compound calendared with steel, polyester, nylon, or other cords. A rubber compound is a blend of ingredients including natural rubber and/or synthetic polymer, carbon black, sulfur, oil, curatives, and pigments. Typical components in a steel belted radial truck tire include:

- Innerliner: A component that provides for air retention of the tire. It can vary in overall thickness, number of laminate plies or shape, and rubber compound.

- Body Ply or Plies: In medium and heavy duty truck tires, typically steel cords that are embedded within a layer of rubber compound to form a fabric sheet/ply that make up the tire's casing. The material properties of the cords, their configuration, and end count can be varied. The number of plies and the configuration of the ply ends are varied by design.

- Beads: A bundle of steel wires and insulating rubber compound that form the foundation for the tire attachment to the wheel by anchoring the body ply or plies and resisting the forces of inflation pressure. Beads can be produced with single steel wires, or multiple wires, wrapped numerous times into various configurations depending on the application.

- Bead Fillers: A component formed of a unique rubber compound that is varied in size and shape to affect the sidewall stiffness of the tire.

- Sidewalls: Various dedicated rubber compounds that form the protective, and decorative, outer side layers of the tire to resist cuts and abrasions and minimize rolling resistance among other roles. The size and shape of these components are customized to match the particular tire for which they are intended, and sometimes have differences from one side of the tire to the other.

- Steel Belt Plies: Fabrics of steel cords embedded within layers of rubber compound, with variable thickness and width dimensions. The cords themselves are composed of numerous brass-plated filaments that can be oriented into various configurations, wire gauges, and spacing. The rubber compound used to surround and interlock with the steel cords is specially formulated to chemically react with and bond to the brass coated steel cords. The cords of each ply are positioned at opposing, variable angles so that when the belt plies are bonded together, they form a package that provides the stiffness and strength to the tread.

- Belt Wedges: Components utilized at the edges and between the steel belt plies that contribute to or optimize the belt package for durability and performance. These items can vary among tires in size, shape, and rubber compound.

- Belt Edge Inserts: Components between the outermost body ply and the innermost steel belt ply edges that contribute to or optimize the belt package for durability and performance. These items can vary among tires in size, shape, and rubber compound.

- Tread: A component comprised of numerous rubber compounds such as the tread rubber that contacts the road, the subtread rubber that is not exposed to the road, and the undertread rubber that covers the entire steel belt package. Each of the compounds can vary and would be chosen to suit the particular tire under consideration.

Other components that can be engineered into a steel-belted radial tire include, but are not limited to: abrasion gum strips, bead wraps, body inserts, sidewall inserts, cap plies, and cap strips.

Bridgestone/Firestone designs and manufactures tires for a large number of vehicles and applications including passenger cars, light trucks, commercial trucks, agriculture vehicles, mining vehicles, and more. These vehicles, and their numerous variations, have different physical characteristics, functions, operating environments, and expectations for performance and, therefore, require different types of tires.

Tires, therefore, are unquestionably designed for the type of service and performance requirements demanded by the vehicles. Differences among the design parameters make individual tires unique from others, and can impact everything from their traction characteristics to their durability properties. These differences exist not only for the numerous tires used for different classes of vehicles, but also for different tires developed for vehicles within a given class. For example, different tires developed for different compact SUV's can have substantial design differences.

Tire Designs in General

Steel belted radial tires are similar to one another only in very general terms (round, black) in the same sense that cars are similar to one another (fenders, windshields, doors, steering wheel, engine). Thus, it is incorrect to believe that all tires, or certain tires, descend from a single tire design. Tires typically take several years to progress through the concept, design, and engineering process, and usually evolve separately over different time frames.

Tire designs also change over time as technology advances. The elements of a tire's structure (including the rubber compounding and the other materials such as polyester and steel), the mold design criteria, and the manufacturing processes advance independently of each other. Where advancements have been made at the component level, as in tread compounding or steel cord tensile strength, they have been selectively engineered into the tires under development or in production at the time, regardless of the original design. Advances in mold designing and tire manufacturing are implemented along the way.

It is difficult to fully categorize tires; however, there are basic categories, such as:

- Passenger
- Light Truck
- Truck-Bus

The truck-bus category is broadened by tire/vehicle market segments, such as the following, recognized in the industry:

- Local
- Regional Haul
- Long Haul
- Extra-Long Haul
- On/Off Highway
- Special Service

They are further broadened by tire design categories, such as the following, that are based on the application and service:

- All-Position
- Drive Axle
- Free-Rolling

- Highway Traction
- Deep Traction
- Wide Base
- Heavy Duty

At the most basic level, the differences between tire categories begin with how passenger, light truck, and truck-bus tires:

- Are standardized differently for size, inflation, and/or load capacity by the Tire & Rim Association and/or the European Tyre and Rim Technical Organization

- Have differing DOT Federal Motor Vehicle Safety Standards for casing strength (plunger), high speed durability, and endurance

- Utilize and have differing industry standard durability tests and requirements

Given all of the above possibilities, and more, tires are designed using variations in their size, construction, and materials to meet a myriad of requirements such as the needs of the vehicle, the expectations of the customer, and the operating conditions. It is then clear why tires are designed, developed, specified, tested, and evaluated differently from one another.

The Tire Development Process

There is no single tire development process. Tires are designed to meet specific needs, many or few. The needs are defined by a number of parameters relating to the vehicles on which the tire is to be used, the type of service, and the market expectations for the tire. Since these items can vary, sometimes substantially, the process for developing tires differs from one to another.

Truck-Bus tires are developed for the trade and original equipment (OE) markets, both of which have specific requirements and objectives for specific vehicles and applications. Trade tires are sold to tire dealers and other retail outlets and are also sold to fleet operations, such as trucking and freight companies. OE tires are sold directly to a vehicle manufacturer for application to newly-produced vehicles.

In addition to the basic requirements for truck-bus tires, such as size and load capacity, the following design elements are typically considered:

- Traction—wet, dry, mud/snow
- Treadwear—longevity and resistance to irregular wear
- Off-Road, Tear Resistance
- Rolling Resistance—related to fuel economy
- Air Permeation—reflects the rate of air loss of the tire

- Noise
- Speed and Durability

Bridgestone/Firestone utilizes state-of-the-art research and technology to design and develop tires. This includes computer modeling of tires, advanced compounding with cutting edge polymers, and leading edge test technology. Noting that limitations of science and engineering require trade-offs in some performance areas versus others, the goal is an optimized tire design given the desired performance parameters—which can be many or few.

Prototype tires are built and tested against the required performance criteria—and built and tested again until the objectives have been met. Testing regimens are designed to meet the requirements of many entities, including the following:

- Fleet, OE, and other aftermarket customers
- The U.S. Department of Transportation (DOT)
- Internal company requirements of Bridgestone/Firestone, which include numerous tire industry standards.

Among the most significant tests conducted and evaluated are durability tests designed to exert extreme forces on tires—numerous tests run the tires to total failure. It is the evaluation of these tested tires that assures the performance desired for the product when it reaches the consumer.

Tire Specifications

Each tire is defined by a specification, and every different specification is an outline for a different product with different performance characteristics. Specifications establish the materials, dimensions, and types of components as well as the particular interrelationship of these components by assembly method, order, and orientation.

Elements of a tire specification include items such as the following:

- The tire size, type, and markings
- The tire assembly method and machine parameters
- The cure type, mold, and other curing equipment parameters
- Rubber compounds, of which most are different formulations, i.e.:
    - Innerliner
    - Body ply skim
    - Abrasion
    - Bead wire insulation
    - Bead fillers
    - Black sidewall
    - Belt edge insert

  - Steel belt skim
  - Belt wedge and gum strips
  - Undertread
  - Tread
- Other materials:
  - Body ply cords
  - Steel belt cords
  - Bead wire
  - Reinforce
- Cured tire parameters

Specifications may vary depending on items such as equipment at a particular plant. They are subject to modification depending on process and design advancements, other improvements, or changes in a customer's requirements. Specifications also vary within tire lines that share a brand or model name, due to having a broad range of tire sizes or load capacities.

The specification and the tire produced from it are both unique. Different tires result in different performance—performance that is dependent on the chemical and composite structure of the whole tire as well as the separate components of the tire and their relationship to one another. Ultimately, these variations and others affect the distribution of forces, stresses, and strains by the tire structure, making the tire different from others in terms of performance factors such as belt stiffness, belt edge strain, temperature generation, air permeation, ride comfort, and handling characteristics.

Post-Development

Once the tire development process is complete and specifications are established, Bridgestone/Firestone's testing and evaluation process does not end—the quality control process requires continual monitoring of tire performance when new and in the field. Prescribed quality control standards and guidelines for tire manufacturing and durability performance assure to a high degree of certainty that the tires produced by Bridgestone/Firestone meet or exceed all applicable DOT, customer, and internal company requirements.

Ultimately, Bridgestone/Firestone's tires reach the consumer and the field where they are subjected to a wide variety of use and operating conditions. Tires are the device through which all the actions of the vehicle are transmitted—accelerating, braking, and turning—to varying degrees as different as the vehicles and the people who drive them. Tires are sub ject to the vehicles they are attached to, the use and maintenance habits of their owners/operators, the environment in which they operate (which is encompassed by extreme heat to frigid snow and ice), and infinitely possible random events that can inflict damage or affect their operation, such as punctures and impacts.

Tire Failures

Over time, as science, engineering, and manufacturing technology has advanced, tires offer an increasingly higher degree of utility, reliability, and value. Naturally, however, tires wear out, can become damaged, and when pushed beyond their limits, they will fail; there has not been a tire produced to date that will not. History shows that there are many types of tire failures, and the long-standing practice of carrying a spare tire continues.

The mere fact that a rapid air loss, separation/detachment, or any other type of tire failure occurs does not indicate that the tire is defective. All makes, models, and sizes of tires are subject to failure, which can occur for a number of reasons not related to the design or manufacture of the tire. Conditions that can cause tire failure include impact damage, road hazard damage, improper inflation, overloading, puncture(s), mounting damage, improper repair or servicing, improper vehicle alignment, improper rim components, and operator driving habits. These conditions result in physical changes to the tire and/or affect the stresses and strains subjected to the tire's components.

Bridgestone/Firestone, and the tire industry in general, has taken a variety of steps to train, educate, and/or warn service personnel and consumers about the use and maintenance/service of tires. The warnings and instructions issued by Bridgestone/Firestone, including on-product warnings, are appropriate, adequate, and consistent with those generally provided in the tire industry.

Selected Reference Materials

1. Bridgestone/Firestone Truck Tire Limited Warranty and Safety Manual
2. Firestone Medium and Commercial Light Truck Tire Data Book, Feb. 2004
3. The Tire and Rim Association, Inc. 2005 Data Book
4. Traffic Collision Investigation, 9th Edition, Northwestern University Center for Public Safety, Evanston, 2001.
5. *Introduction to Tire Safety, Durability, and Failure Analysis*, Gardner and Queiser, Chapter 15 of The Pneumatic Tire, NHTSA DOT Contract DTNH22-02-P-07210, Washington, D.C., 2005
6. *Care and Service of Truck and Light Truck Tires*, RMA HTM-2-98
7. 49 CFR: §393.75, §570, §571.119, §571.120, §574
8. *Radial Tire Conditions Analysis Guide*, Third Edition, Technology & Maintenance Council of American Trucking Associations, Inc., 2004